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Fecundity of Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*)

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Abstract

Relations between fecundity and length (cm) ($F = 1.155 \times 10^{-7} \times L^{4.598}$) and fecundity and weight (g) ($F = 2.539 \times 10^{-4} \times W^{1.439}$) were established for Greenland halibut in the North East Arctic, based on a total of 95 ovaries collected near the Bear Island, Barents Sea, in September 1996. The fecundity ranged from 6 800 to 70 500 eggs per female. The Greenland halibut were mainly in maturity stage 4, which is by definition, vitellogenic oocyte size between 2 and 4 mm in diameter. Mean gonadosomatic index (GSI) was 7.5% (range 2.0-13.5%).

Because of recruitment failures and a historic low spawning stock biomass, the Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*) has been strongly regulated in the 1990s. Fecundity, which is defined as the number of vitellogenetic oocytes developing in each female prior to the spawning season, is important for understanding spawning-stock-recruitment relationships. The relation between the fecundity and length for Northeast Arctic Greenland halibut stock has not been previously established.

Introduction

Greenland halibut (*Reinhardtius hippoglossoides* Walbaum) in the Northeast Atlantic is distributed mainly on the continental slope off Norway from 62°N to the regions north of Spitsbergen. It is observed down to 1 400 m. In other parts of the Atlantic, Greenland halibut is observed down to 2 000 m (Boje and Hareide, 1993). It is described as a boreal-arctic species and is found mainly at temperatures between -1° and 4°C. The population constitutes a separate management unit in the ICES management system.

During the late-1980s a drop in the Greenland halibut year class indices was observed. This was based on the regular 0-group and juvenile surveys, and a historic low spawning stock biomass were observed (Hylen and Nedreaas, 1995; Smirnov, 1995). Parallel to this, the importance of Greenland halibut as a commercial fish species increased. There was also a decrease in the commercial catch per unit of effort (CPUE) and this lead to strong regulations including a fishing ban north of 71°30N from 1992.

Studies of fish reproduction and stock-recruitment relations are basic issues in the work of precautionary approach, to prevent a stock collapse. Fecundity, which is defined as the number of eggs developing in a female for the following spawning season (Bagenal, 1978) is important for obtaining data on population stability and year-class strength. Generally, deepwater species along with Arctic and Antarctic species produce fewer and bigger eggs than related boreal species (Marshall, 1953). Fecundity is usually related non-linearly to total fish length and weight. The relations are usually allometric (Bagenal, 1978).

Little work has been done on Greenland halibut fecundity, particularly in the Northeast Atlantic. Millinsky (1944) estimated fecundity of two Greenland halibut females in the Barents Sea. In the Northwest Atlantic a few investigations on Greenland halibut have been conducted. Lear (1970) examined 45 females from the Newfoundland-Labrador area. Bowering (1980) examined 153 females from Southern Labrador and the South-eastern Gulf of St. Lawrence. Jensen (1935) estimated the fecundity of one female in West-Greenland waters. In East-Greenland waters a fecundity-length relationship is presented for 1996 (Rønneberg *et al.*, 1998).

This paper describes the results of a fecundity study of Greenland halibut in the Norwegian and Barents Seas. The objectives were to obtain relations between fecundity and length, and fecundity and weight.

Materials and Methods

The ovaries were collected in September 1996, from fish caught using gillnets and longlines on the continental slope west of Bear Island (Fig. 1). The combined sample consisted of 95 females randomly chosen from the catches. The females were maturing with egg diameters of 2-4 mm (visual), which implies that spawning would have likely occurred a few months later. The ovaries were frozen at sea and preserved in 3.6% phosphate and then approximately one month later stored in buffered formaldehyde.

For the present study, the gravimetric method described by Bagenal and Braum (1978) was used. The procedure for estimating the number of eggs in an ovary was: measure the total weight of the ovary after fixation, collect 4 subsamples, store the samples in 70% ethanol, establish a raising factor (R_{xy}) for each sample based on sample weight and ovary weight (i), count the number of eggs in sample 1 and 2, and estimate the total number of eggs (defined as the fecundity) in the ovary (ii). If the coefficient of variation (CV) (v) between the two samples (1 and 2) exceeded 5%, samples 3 and 4 were counted. The eggs were counted using a light microscope.

Raising factor was defined as (i):

$$\text{(i)} \quad R_{xy} = GW_x / SW_{xy}$$

R_{xy} = Raising factor for ovary x and subsample y, GW_x = gonad weight after fixation of ovary x, and SW_{xy} = subsample weight of ovary x, subsample y.

Fecundity was estimated by the equation (ii):

$$\text{(ii)} \quad F_{xy} = R_{xy} \times N_{xy}$$

F_{xy} = fecundity of ovary x, subsample y, R_{xy} = Raising factor for ovary x and subsample y, and N = number of eggs counted ovary x, subsample y.

Gonadosomatic index (GSI) is defined as the relation between the gonad weight (GW) (g) and the total weight (W) (g) of the fish (iii).

$$\text{(iii)} \quad GSI = (GW \times 100\%) / W$$

Hepatosomatic index (HSI) is defined as the relation between the liver weight (LW) (g) and the total weight (W) (g) of the fish (iv).

$$\text{(iv)} \quad HSI = (LW \times 100\%) / W$$

Subsample size

An acceptable subsample size was established by comparing the fecundity obtained from an analysis of subsamples taken from the same ovary. Subsamples of 1.7 g were used due to a coefficient of variation below 5%, corresponding to more than 200 eggs per sample.

Types of oocytes

Three types of oocytes were discovered. Vitellogenic oocytes assumed to become spawning eggs in a few months, were defined as G1. Oocytes of significant smaller diameter with yolk, were defined as G2. Small previtellogenic oocytes were defined as R (recruit group). As the ovaries had been frozen, oocyte diameter was not measured. The number of G1 oocytes is the fecundity estimate for an ovary.

Homogenity

Homogenity was tested by comparing four different ovarian sections; anterior, middle and posterior section of the right lobe and the middle section of the left lobe. Five ovaries were analysed, and from each section four subsamples were taken.

Data analyses

The Excel-97 was used in the data analyses.

Relations between fecundity and length and fecundity, and weight were established using log-log-transformed regression.

The coefficient of variation (CV) was used in the analyses to evaluate the fecundity estimates (v). The coefficient of variation (expressed as %) is the standard deviation (std) of the estimates divided by the mean fecundity (F_{mean}) (Sokal and Rohlf, 1995).

$$\text{(v)} \quad CV = (std \times 100\%) / F_{mean}$$

Results

Homogenity

The fecundity of the 5 chosen ovaries varied from 20 000 to 35 000 eggs. A comparison of the midsections of the two lobes within each ovary, indicated a minor variability between the two lobes. No systematic trend was, however, observed (Table 1). The right midsection CV was in the range 1.3-5.5%. The CV of the left midsection was in the range 1.9-5.5%. No systematic difference in the fecundity estimates, based on samples from any of the four sections was observed (Table 1). Therefore, subsamples from the middle section of the right lobe were regarded as representative for the ovary, and the egg counts were based on subsamples taken in this section.

Fecundity of Greenland halibut

Total length of the Greenland halibut females of the combined sample ranged from 48 cm to 80 cm. Mean length of the combined sample was 65.2 cm (std = 6.0, N = 95). Fecundity estimates ranged from 6 800 to 70 500 eggs per female. Mean fecundity was 28 100 eggs (std = 13.7, N = 95).

The relationship between fecundity (F) and length (L) (Fig. 2) of the combined sample is:

$$F = 1.155 * 10^{-7} \times L^{4.598} \quad (r^2 = 0.68, p < 0.005).$$

The fecundity is expressed as 1 000 and the length is given as total length in cm.

The relationship between fecundity (F) and weight (W) (Fig. 6) of the combined sample is given by:

$$F = 2.539 \times 10^{-4} \times W^{1.439} \qquad (r^2=0.77, p < 0.005).$$

The fecundity is expressed as 1 000 and the total weight is in grams.

Gonadosomatic index (GSI)

Gonadosomatic index (GSI) is defined as the relative portion of which the ovaries constitute of the total weight. For the combined sample, GSI was in the range 1.9-13.5%. Mean GSI was 7.5% (std = 2.2, N = 95). A weak, but significant ($p < 0.005$) increasing trend of GSI related to length was observed (Fig. 4). Fecundity showed an increasing trend with increasing GSI (r^2 = 0.50, N = 95) (Fig. 5). The correlation was significant ($p < 0.005$).

Hepatosomatic index (HSI)

Hepatosomatic index (HSI) describes the relative portion of liver in each female relative to total body weight. HSI was in the range 0.3–4.6%. Mean HSI was 2.4% (std = 1.1, N = 37). No significant relation between HSI and total fish length was observed (Fig. 6). Fecundity showed a weak, but increasing trend with increasing HSI (Fig. 7). Like for the GSI-fecundity plot (Fig. 5) the scatter was wide. No significant relation between fecundity and HSI was observed ($r^2 = 0.10$, N = 37, $p > 0.05$).

Discussion

Greenland halibut included in the fecundity study were sampled in mid September 1996. The ovaries were mainly in maturity Stage 4, which is, by definition, eggs with a diameter of 2-4 mm (Nielsen and Boje, 1995). Spawning had not started but was expected to occur within a few months time. This is in accordance to egg development and results from investigations carried out in the same area in 1996 and 1997, describing the spawning of Greenland halibut (Albert *et al.*, 1998; Stene *et al.*, 1998). The eggs were easily classified and counted, as the difference between G1 and G2 was obvious.

Gonadosomatic indices (GSI) ranged 2.0-13.5. Fedorov (1968) assumed that Greenland halibut prior to spawning undergo an increase in gonad weight, the GSI reaching 15-18% as spawning is likely to occur. In West Greenland waters GSI for Greenland halibut is reported to increase from 1-3% in April-July to *ca.* 10% in October (Jørgensen and Akimoto, 1990). A study conducted in East Greenland waters in 1997 (Rønneberg *et al.*, 1998) reported GSI in the range 1-5% in July.

In the Barents Sea the GSI is observed to increase from a minimum in February-April towards spawning in November-January (Gundersen and others in prep.(a)). This verifies that the maturity process is in progress in the period of sampling, however, not overlapping with the time of spawning.

The fecundity of Greenland halibut showed a slightly better relationship to weight than to length, however, both relations were significant ($p < 0.005$). In the fecundity-length-relationship the exponent b was estimated to 4.598. Bagenal (1978) stated that the exponent may range from *ca.* 2.3 to 5.3, most often seen a little above 3. The exponent b is therefor in the interval described by Bagenal (1978).

Sampling of the ovaries was random. The sampling was conducted from one longline setting and one gillnet setting. The samples were taken during a multigear survey in September 1996, and so the sampling has been conducted over a relatively short period of time.

Prior to the study described in this paper, only a few egg counts have been conducted for Greenland halibut in the Northeast Arctic. Millinsky (1944) estimated a fecundity of 28 000 and 33 000 for two Greenland halibut females in the Barents Sea. This is within the same range as the results of the present study. Further analyses on the fecundity of the Greenland halibut in the Northeast Arctic are in progress (Gundersen and others in prep., (b)).

In the Northwest Atlantic a few investigations on the fecundity of Greenland halibut have been conducted. In the Newfoundland-Labrador area, the fecundity was in the range 15 000 to 215 000 (Lear, 1970). A curved relationship based on 45 females collected over the period 1967-1969, was established. Bowering (1980) compared the results obtained by Lear (1970) to fecundity samples collected in the Southern Labrador and the South-eastern Gulf of St. Lawrence in 1976-1978. The equation presented by Lear (1970) indicated a higher fecundity for Greenland halibut bigger than 80 cm than the equation presented by Bowering (1980). The period of sampling for the two studies may bias the results as Lear (1970) sampled the ovaries over the period March-October, whereas the results presented by Bowering (1980) was based on samples collected over a shorter time period; October-November. The great time span in season for the samples taken in 1967-1969, and the relatively few samples collected over three years may give considerable variation in estimates both due to growth during the year and annual fluctuations in fecundity.

Using the relationship between fecundity and length presented in this paper, a 70 cm female Greenland halibut in the Barents Sea is likely to produce 35 000 eggs on average. In the Labrador area, the fecundity–length–relationship indicated that a 70 cm long female produced 30 000 eggs on average. In the Gulf of St. Lawrence a 70 cm female produced 50 000 eggs on average (Bowering, 1980). This indicates a geographic variation in fecundity.

Jensen (1935) estimated the fecundity of one female (101 cm) in West-Greenland waters to 300 000 eggs. In East Greenland waters fecundity was estimated to be in the range 32 000–277 000 eggs (Rønneberg *et al.*, 1998). This is a considerably wider range of fecundity than observed for the present study in the Barents Sea. However, the fecundity estimates presented for East-Greenland waters (Rønneberg *et al.*, 1998), and Southern Labrador (Lear, 1970) are based on Greenland halibut in a wider length range, including larger fish than in the present study.

In Icelandic waters ovaries from 5 Greenland halibut females were analysed for fecundity in March 1977 (Magnusson, 1997). The fecundity was in the range 17 500 (66 cm) to 42 200 (74 cm). The largest Greenland halibut was 96 cm, showing a fecundity of 37 600. The egg diameter of the ovaries was in the range 2-4mm. The results cooresponds to the results of the present study. However, as the sampling is conducted in May, the maturation seem to follow other seasonal patterns than observed in the Barents Sea.

Fecundity for Northeast Arctic Greenland halibut showed an increasing trend with increasing GSI ($r^2 = 0.50$, $p < 0.005$). The scatter of the fecundity-GSI plot was wide. The same was also observed for Greenland halibut in East Greenland waters, but a correlation coefficient was not presented (Rønneberg *et al.*, 1998).

A significant relation between fecundity and HSI was not observed. The scatter was wide, corresponding to the results from Greenland halibut in East Greenland waters (Rønneberg *et al.*, 1998). A more comprehensive study regarding the effects of length, weight, gonad weight, GSI, liver weight and HSI on fecundity is in progress (Gundersen and others in prep, (b)).

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References

Albert, O.T., E.M. Nilssen, A. Stene, A. Gundersen & K.H. Nedreaas. 1998. Spawning of the Barents Sea/Norwegian Sea Greenland halibut (*Reinhardtius hippoglossoides*). ICES CM 1998/O:22.

Bagenal, T.B. 1978. Aspects of fish fecundity in ecology of freshwater fish production. Blackwell Scientific Publications: 75-102.

Bagenal, T. B. & E. Braum. 1978. Eggs and early life history. *In*: T. M. Bagenal (ed.), "IBP handbook. Methods for assessment of fish production in fresh waters", 3, Chapter 7: 165-201.

Boje, J. & N.-R. Hareide 1993. Trial deepwater longline fishery in the Davis Strait, May-June 1992. NAFO SCR. Doc. 93/53, N2236, 6pp.

Bowering, W.R. 1980. Fecundity of Greenland Halibut (*Reinhardtius hippoglossoides* Walbaum), from southern Labrador and South-eastern Gulf of St. Lawrence. "Journal of Northwest Atlantic Fisheries Science", 1: 39-43.

Fedorov, K.Y. 1968. Oogenesis and sexual maturity cycle of Greenland halibut. Trudy PINRO: 425-451.

Gundersen A. C. and others. In prep. (a) Maturation of Greenland halibut of Northern Norway. A field study conducted in 1997.

—— in prep. (b). Fecundity study of Greenland halibut based on a field study conducted in 1997.

Hylen, A & K.H. Nedreaas. 1995. Pre-recruit studies of the North East Arctic Greenland halibut stock: 229-238. Hylen, A [ed.] "Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea and adjacent waters". Proceeding of the sixth IMR-PINRO Symposium, Bergen 14-17 June 1994. Institute of Marine Research, Bergen 1995.

Jensen, A.S. 1935. The Greenland halibut (*Reinhardtius hippoglossoides* (Walb.)) it's development and migrations. "Det Kongelige.Danske Videnskabs Selskabs Skrifter, Naturvidenskabelig Mathematisk Afdeling" 9(VI/4): 35p.

Jørgensen, O. A. & K. Akimoto. 1990. Results of a stratified random bottom trawl survey in NAFO sub-area 1 in 1989. NAFO SCR. Doc. 90/39, Serial No. N1756, 14p.

Lear, W.A. 1970. Fecundity of Greenland Halibut (*Reinhardtius hippoglossoides)* in the Newfoundland-Labrador Area. "Journal of Fisheries Research Canada", 27 (10): 1880-1882.

Magnusson, J. V. 1977. Notes on eggs and larvae of Greenland halibut at Iceland. ICES CM 1977/F:47.

Marshall, N.B. 1953. Egg size in Antarctic and deep-sea fishes. "Evolution", 7, 328-341.

Millinsky, G.J. 1944. On the biology and the fisheries of the *Reinhardtius hippoglossoides* (Walbaum) of the Barents Sea. "The Bottom Food-Fishes of the Barents Sea", 8: 375-387, Moscow.

Nielsen, J. G. & J. Boje. 1995. Sexual maturity of Greenland halibut at West Greenland based on visual and histological observations. NAFO Scr. Doc. 5/18, Serial No. N252

Rønneberg, J.E., A.C. Gundersen & J. Boje. 1998. Fecundity of Greenland halibut (*Reinhardtius hippoglossoides*) in East Greenland waters, July 1997. ICES CM 1998/O:26.

Smidt, E. L. B. 1969. The Greenland halibut, *Reinhardtius hippoglossoides* (Walb.), biology and exploitation in Greenland waters. "Meddelelser fra Danmarks Fiskeri- og Havundersøgelser", 6(4): 79-148.

Smirnov, O.V. 1995. Dynamics of Greenland halibut recruitment to the Norwegian-Barents Sea stock from 1984-1993 trawl survey data. pp. 239-242, *in*: Hylen, A. [ed.] "Precision and relevance of pre-recruit studies for fishery management related to fish stocks in the Barents Sea and adjacent waters". Proceedings of the sixth IMR-PINRO Symposium, Bergen 14-17 June 1994. Institute of Marine Research, Bergen 1995.

Sokal, R.R. & F.J. Rohlf. 1995. Biometry. The principles and practice of statistics in biological research. Third edition. W.H. Freeman & Company, New York 887p.

Stene, A., A. Gundersen, O.T. Albert, P. Solemdal, & K.H. Nedreaas. 1998.Early development of Northeast Arctic Greenland halibut (*Reinhardtius hippoglossoides*). ICES CM 1998/O:27. Poster.

TABLE 1. Mean fecundity (F_{mean}) and coefficient of variation (CV) for five Greenland halibut ovaries studied for homogenity. From each section four samples were analysed. L-M = Left lobe midsection, R-A = right lobe anterior section, R-M = right lobe midsection, and R-P = right lobe prosterior section.

	L-M		R-A		R-M		R-P	
Ovary number	F_{mean}	CV	F_{mean}	CV	F_{mean}	CV	F_{mean}	CV
45	32.6	4.5	32.5	2.1	32.3	2.5	27.7	5.4
59	23.0	1.9	28.1	9.5	23.7	3.3	28.2	9.2
66	30.3	3.9	23.8	1.9	33.0	4.5	23.4	2.1
79	20.6	5.5	32.9	3.7	19.8	5.5	33.9	1.6
84	28.6	2.6	18.8	8.1	30.2	1.3	20.0	3.5

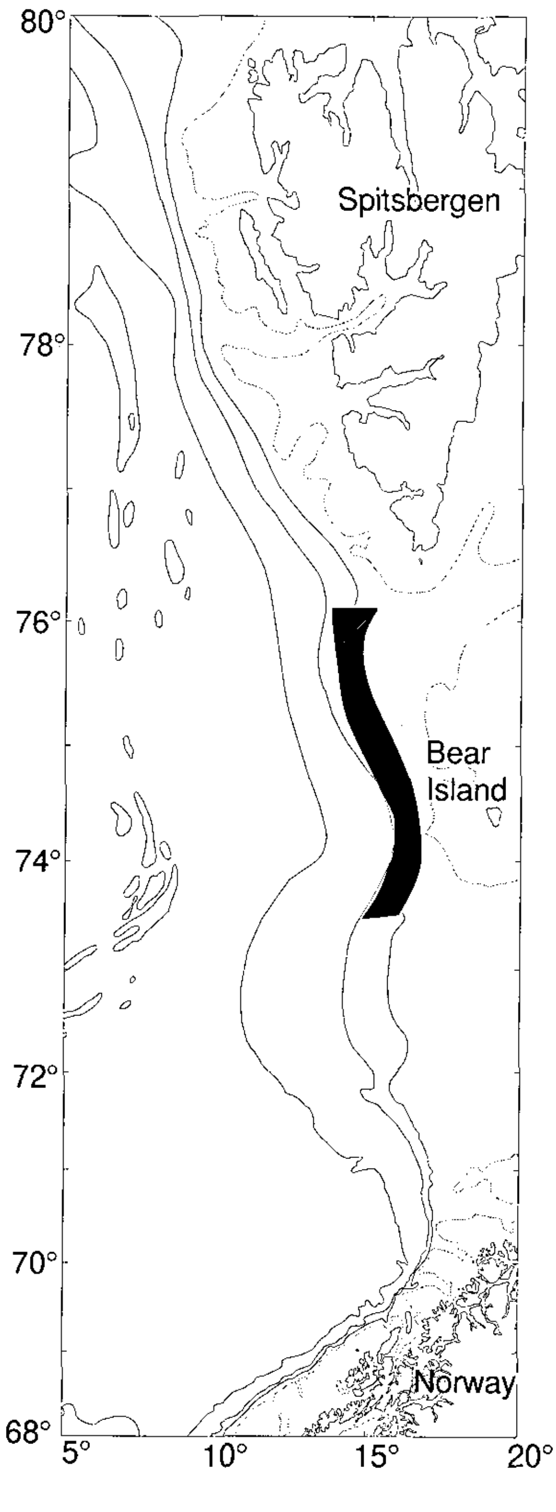

Fig. 1. Sampling areas for Greenland halibut used in the fecundity study. Samples were taken during the Autumn Survey conducted by the Institute of Marine Research, Bergen in 1996, west of the Bear Island.

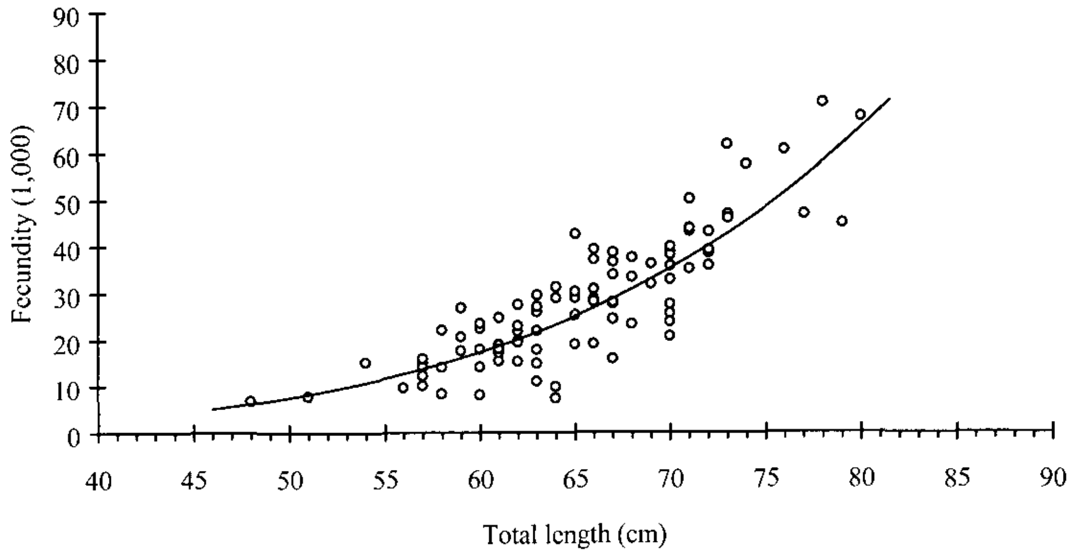

Fig. 2. Fecundity (1 000) of Northeast Arctic Greenland halibut related to total length. $F = 1.155 \times 10^{-7} \times L^{4.598}$ ($r^2 = 0.68$).

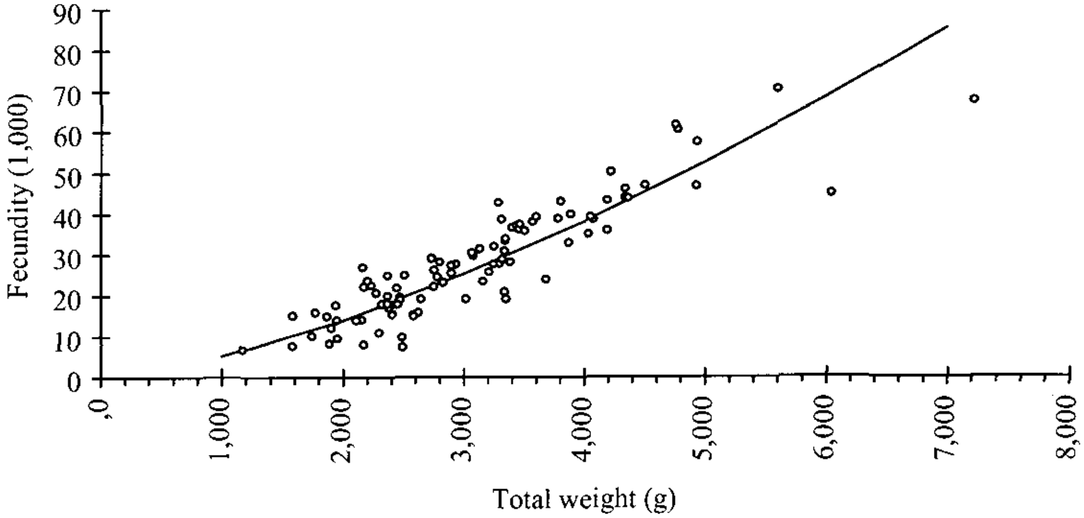

Fig. 3. Fecundity (1 000) of Northeast Arctic Greenland halibut related to total weight (g). $F = 2.539 \times 10^{-4} \times W^{1.439}$ ($r^2 = 0.77$).

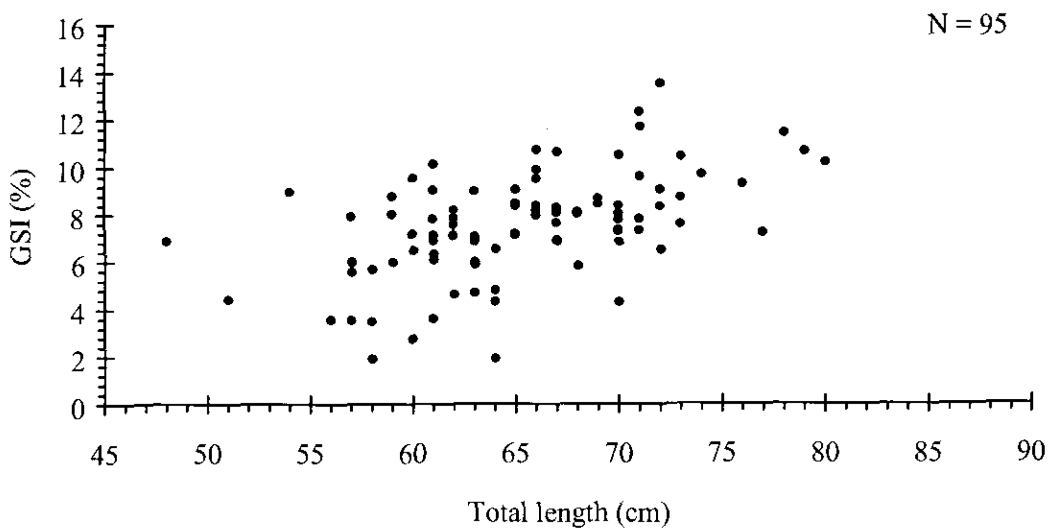

Fig. 4. Gonadosomatic index (GSI, %) of Greenland halibut related to total fish length (cm).

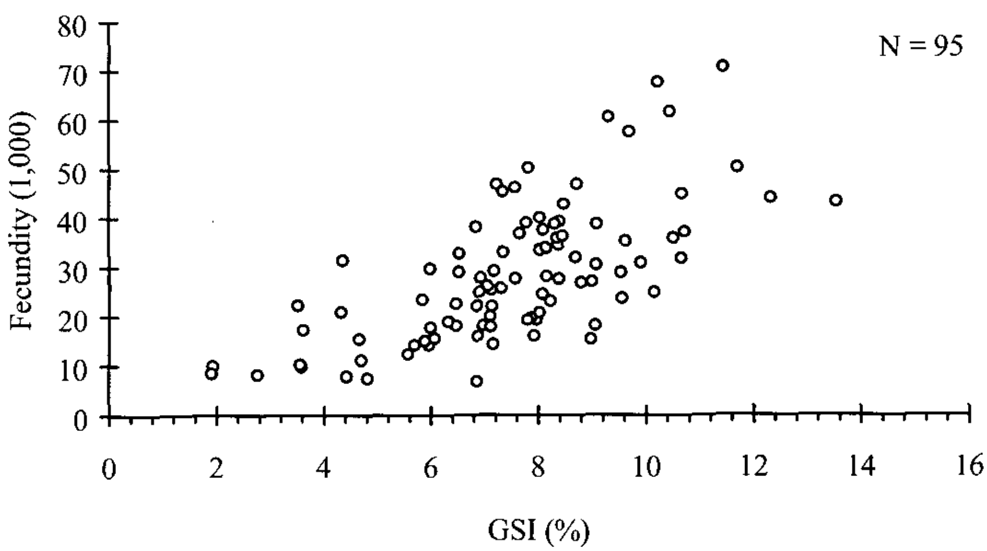

Fig. 5. Fecundity (1 000) of Greenland halibut related to GSI (gonadosomatic index, %).

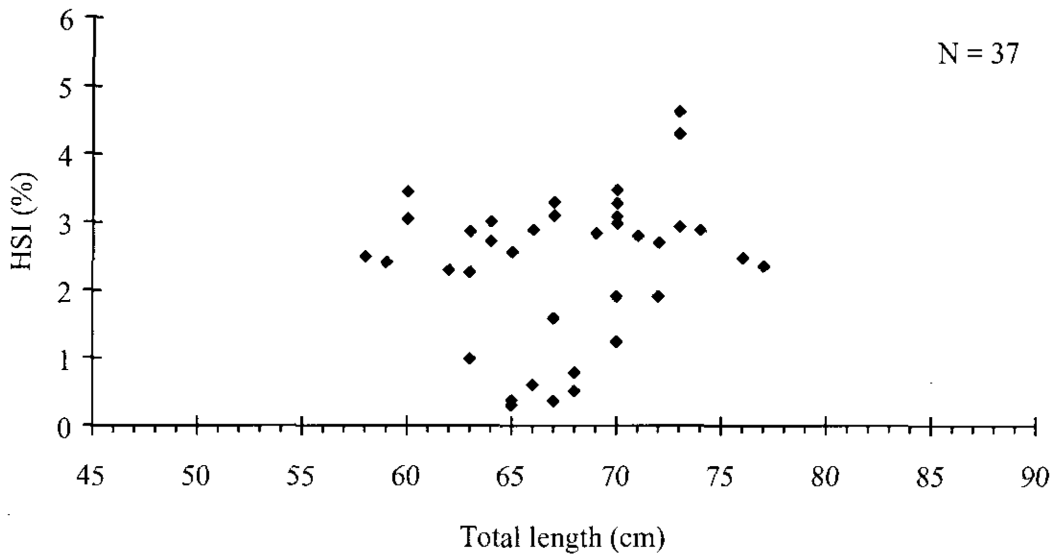

Fig. 6. Hepatosomatic index (%) of Greenland halibut related to total fish length (cm).

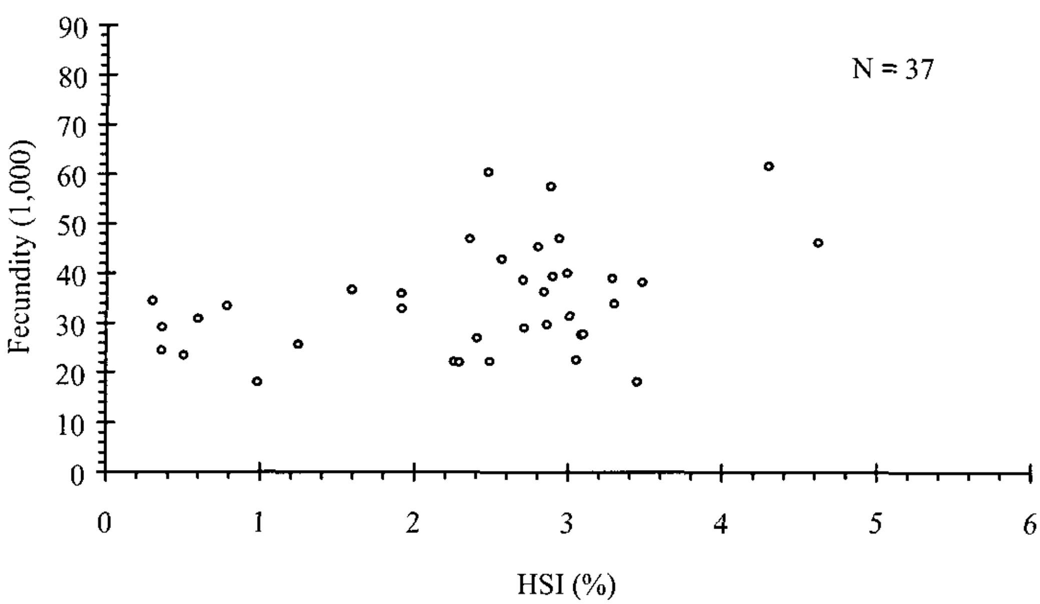

Fig. 7. Fecundity (1 000) of Northeast Arctic Greenland halibut related to HSI (hepatosomatic index, %).